Making insulating Al_2O_3 electrically conductive with a small amount of ITO grain boundary phase by pressureless sintering in air atmosphere

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Sintered Al_2O_3 has excellent mechanical properties and chemical inertness, although low process cost as its densification is attained by pressureless sintering in air atmosphere. Therefore, it is the most applied ceramics in the fields of machine and electronic parts. However, since Al_2O_3 is an insulator with 10^{-16} S/cm, the electrical conductivity of insulating Al_2O_3 must be controlled between 10^{-5} and 10^{0} S/cm, when Al_2O_3 parts are employed for semiconductor manufacturing equipment. In order not to lose the advantages of Al_2O_3 ceramics, it is necessary to control electrical conductivity using a small amount of conducting phase by sintering in air atmosphere. Indium tin oxide (ITO) is well known as a transparently conductive thin film material, which can be produced by heat treatment in air atmosphere. ITO is thought to be one of most candidates of conductive second phases, because Al_2O_3 hardly reacts with indium oxide and tin oxide. Since shape of ITO grain is not extreme anisotropy such as CNT and graphene, it is impossible to form conducting pathway by percolation of a small amount of ITO. In recent years, in order to give electrical conductivity to insulating material, our research group has proposed an excellent method that precipitates an electrically conductive material at grain boundaries. Although volume of grain boundary phase is several %, it propagates three dimensionally in a sintered body. Therefore, by precipitating electrically conductive ITO at grain boundaries in insulating Al_2O_3 matrix, it is possible to increase conductivity of Al_2O_3 ceramics.

The purpose of this study is to increase electrical conductivity of insulating Al_2O_3 by pressureless sintering in air atmosphere and precipitating ITO of several mol.% at grain boundaries and to evaluate translucency of conductive Al_2O_3/ITO composites.

Three-dimensionally ITO conductive pathways were formed at grain boundaries in Al_2O_3 matrix by sintering Al_2O_3 with 1-3 mol.% (0.75-4.45 vol.%) ITO at a higher temperature such as 1700 °C, which is much higher than a general sintering temperature of 1500 °C. The addition of only 0.5 mol.% (0.75 vol.%) of In_2O_3 doping 1 wt.% SnO_2 was able to increase the conductivity to 1.0×10^{-3} S/cm from 10^{-16} S/cm of monolithic Al_2O_3 (Figure 1). The Al_2O_3/3 mol.% In_2O_3:10%Sn has the highest electrical conductivity of 2.0×10^{0} S/cm. Furthermore, the Al_2O_3/1mol.% ITO containing less than 1 wt.% of SnO_2 in ITO demonstrated excellent conductivity and translucency by pressureless sintering in air (Figure 2)[1].

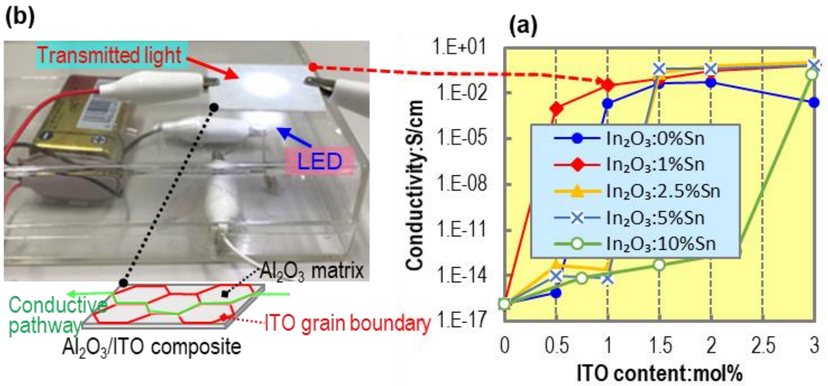

Figure 1(a). Relationship between electrical conductivity of Al_2O_3/ITO composites, ITO contents, and compositions of doped SnO_2 in ITO. (b) Lighting test of LED using Al_2O_3/1 mol% In_2O_3:1%Sn conductive path by battery voltage of 15 V. The light irradiated by LED penetrated through the conductive Al_2O_3 composites.

[1] T. Kusunose, T. Sekino, *Scr. Mater.*, vol. 124, pp.138-141 (2019)